# Waving of the Coal Measures.

HON. ANDREW ROY.

The manner of the formation of coal seams has been a subject of great interest to geologists ever since geology became a science. As early as the year 1785 Sir James Hutton, in an article on the "Theory of the Earth," published in the transactions of the Royal Society of Edinburgh, recognized the vegetable origin of coal. Later, Bischoff and others held that the carbonaceous matter from which coal is derived was formed from drift wood which had been carried down rivers into bays and estuaries, after the manner of the vast rafts of dead floating trees which now accumulate in the lower Mississippi River. This theory was very generally accepted until the year 1840, when Sir William Logan, during his survey of the South Wales coal fields, pointed out the fact that the floor of every coal seam in that coal field was penetrated with rootlets, stems and stumps of trees, and he advanced the view that the vegetable matter from which coal is delivered had grown, decomposed, and mineralized on the spot where we now find the coal. An examination of the floor of other coal fields showed the same conditions as those met in South Wales, and the view of Sir William Logan is now the theory held by all intelligent persons.

Every coal seam represents a vast swamp, or marshy plain, which skirted a shallow sea. Over this marsh there spread a profuse and luxuriant vegetation, consisting of numerous plants, from small mosses to stately trees, which year after year dropped their leaves and fruit, and in time died themselves, and were succeeded by new growths. Thus growth and decay went on through many slowly moving centuries, until there was accumulated a thick and mingled mass of vegetable tissue, like the pulpy mass of a modern peat bog. Finally, through the agency of subterranean forces, the land slowly and gradually sunk, and was covered by the waters of the ocean, which brought in mud, sand and other sedimentary materials, which settled over the old plain, and solidified into shales, sandstones, and associated strata, as we now find them in the coal measures. The buried peat bog became compressed by the accumulated weight of the ocean detritus, the original plants and peatty tissue matting together and mineralizing into the coal, as we now find it in the mine.

The subsidence period was in time arrested, the waters of the shallow ocean retreated to the east, and a second swamp or marshy plain was formed. Generations of forests again succeeded each other, until matter was accumulated for a second seam of coal; then came a second downward movement of the land and another burial of the coal vegetation by the mud and sand of the overflowing sea.

The set of processes thus described was repeated in the formation of every coal seam and its associate strata.

This theory recognizes a low, level plain for the floor of every coal seam, and a uniform subsidence of land in building up the superincumbent strata. But there exists in the coal measures what Prof. Lesley, of the Pennsylvania Geological Survey, has called the mysterious universal waving of the coal measures. There are also great areas of barren ground where seams of coal are due which have been perplexing to the geologist. The causes of the waving strata and of the barren coal areas will form the subject of discussion of this paper. When we examine the mines in any of the lower coal seams of the slate series, we generally find, at one point or another in the workings, the floor of the coal rising at a pitch out of all proportion to the natural inclination of the strata. As we ascend these subterranean hills the seam gradually loses height until it encounters a reverse dip, or disappears altogether. In the lower coal of the series these hills are more marked than in any of the overlying beds, the changes of level being 30 and 40 feet in distances of a few hundred feet. Generally in such cases the underlying strata do not conform to the pitch of the coal; on the contrary, they maintain their normal level while the vein is rising at the rate of 15° to 20°. The coal and underlying strata are thus unconformable.

The hollows in which we find the coal were formed by erosive agencies before the coal vegetation grew. The lines of direction of these troughs in the Mahoning Valley, at least, are generally a little to the west of south; they seldom exceed half a mile in width, and many of them are only a few hundred feet. That they were formed by erosive agencies, as the valleys of the present day were formed, is demonstrated by the level sheets of the shale and sandstone which underlie the coal a few feet, alike on the highest hills and the lowest valleys of the mine.

When the coal vegetation took root and grew in these hollows the highlands which flanked the carbonaceous forests were fully 150 feet higher than the bottom of the swamp. No coal vegetation seems ever to have grown on the highlands of the old plain at the time of the accumulation of the coal material in the valley below. Forty to 50 or 60 feet seem to have been the limit at which the coal plants flourished, for at this distance from the bottom of the swamp the coal thins down to a feather edge and disappears altogether.

It has been estimated that it would require 10 to 12 feet of thickness of the loosely matted vegetable detritus to form one foot of coal. When, therefore, the carbonaceous matter had all accumulated to form the four foot coal of the Mahoning Valley, the center of the peat bog in the middle of the swamp would be 40 to 50 feet thick, while on the hill sides at the edge of the line of vegetation, it would only be one or two feet. After the subsidance occurred, and the sediments of the ocean settled over the coal marsh, the loosely matted vegetable material would bend in the center by the weight of the ocean sediments until it would become compressed to four feet of thickness. Hence, when the pause occurred and the second coal marsh was formed, there would be still an irregular floor winding up and down, as in the case of the floor of coal No. 1, though in a less degree. As coal No. 2 is met directly above No. 1 in the Mahoning Valley, the high lands of the border would be still 120 feet higher than the floor of No. 2. In drilling for No. 1 in the Mahoning Valley, it is not unusual to encounter both of these seams in place, while a few hundred feet distant the older formation of the Cuyahoga shale is met 50 to 60 feet, and in some cases 100 feet higher than the level of No. 1. A case of this kind is reported by Prof. White, of the Geological Survey of Pennsylvania, in Vol. QQQ, page 108. A hole was drilled on Keel Ridge, Mercer county, for the Sharon coal; it went through the coal material at the depth of 186½ feet, but was sunk 235½ feet, the last 66 feet being in the "bottom rock" of the drillers, though the hole was not yet down to the coal level. Prof. White, who seems not to have understood the unconformable character of the strata, intimates, because the hole was not sunk to the coal level, that the existence of the Sharon coal at that point had not been definitely settled. In this case the coal driller was a better geologist than the scientific man. The driller may not have known the geological reason for the older formation appearing so high above the coal level; but experience had taught him that it was to no purpose to look for coal after his chisel had cut into the bottom rock.

This unconformable character of the strata is so well marked in the lower coal that he who runs may read. But we have conclusive evidence that several of the overlying seams are also imbedded in basins formed by erosive agencies. In the Wellston coal I recently examined a mine in one of the entries of which the coal rose in a subterranean hill to a height of fully 70 feet. The entry was stopped before the top of the hill was reached, the coal, which was four feet thick in the low ground, having gradually thinned down to 18 inches at the face of the entry. Three dikes were encountered on the way—an unusual thing in an Ohio mine — in two of which the upthrow was nearly four feet in each dike. To make height for the mule road the floor of the entry had been blasted, and it was found on examination that the strata below ran level, while the coal was pitching at the rate of 12° to 15°. Similar conditions have been met in other mines of this field, though this is the highest hill encountered so far.

The coal, in rising on these subterranean hills, mainly loses height from the bottom of the seam. In a mine in Coshocton county, I followed a seam till it rose on a hill twenty feet or more above its normal level. There is a shale band running through this coal a foot or fifteen inches above the floor. The lower bench, in ascending the hill, gradually lost in thickness, till it disappeared altogether, while the height of the upper bench was scarcely affected. Here is a demonstration of the manner in which the carbonaceous material accumulated. The vegetation grew in the low grounds, while the hill sides, which afterward became spread with the coal flora, were yet barren ground. A subsidence of only a few inches occurred, and the water was let in over the coal marsh. It came quietly, and deposited its sediment evenly and with great uniformity. The land became stationary again; and again the coal flora grew, until material for the lower bench had accumulated.

A better demonstration than the foregoing occurs in the mines at Mineral Ridge, in the Mahoning Valley, opened on Coal No. 1. The seam is divided into two benches by a band of gray shale, varying from a foot to seven feet in thickness. Below this shale band, and resting directly on the lower coal bench, the seam of black band ore, from four to fourteen inches thick, comes in. The floor of the mines is very undulating, and the coal frequently rises over a hill and dips into an adjoining swamp. In such cases the lower bench of coal first loses height, until it thins out altogether; then the black band becomes affected, and it, too, thins out; then gray shale gradually disappears, the upper bench of coal meantime maintaining its usual height. If the hill continues to rise it, too, becomes affected, and finally disappears; but if the hill flattens off, the upper bench remains bravely in place, until a dip is encountered, in following which the shale, black band and lower bench of coal reappears in the reverse manner in which they were cut out.

Coal seams sometimes split up into two parts in other regions of the State, or conversely two coals come together. The great vein of the Hocking Valley is 9 feet thick at Doanville, while at Nelsonville, two and one-half miles north, it is only 6½ feet in height. But if we examine the roof shales in the Nelsonville mines, we recognize a rider 2 feet in thickness, and it is this rider which unites with the main coal at Doanville which makes the 9 foot coal. This rider is not *6 a* of the State Geological Reports, but a local bed—an off-shoot of the great vein, so to speak. In a mine at Zaleski, in Vinton county, the seam splits in two, and the benches get 14 feet apart. At Steubenville also an off-shoot of the main coal, which first occurs in the Stoney Hollow mine, diverges 12 feet in the Market street shaft.

An explanation of the above on similar facts has been given by geologists that the coal marsh experienced a local depression, which became filled with sediment, making a new soil for the coal vegetation. If, however, we examine the foreign material which separate the benches, we will find its stratified beds conforming to the lower rather than to the upper coal, demonstrating that the subsidence was quiet, even and uniform; and that erosion must have removed the muddy sediment, which flowed over the coal marsh, after the land had sunk, laying bare the coal vegetation over a considerable area, and only partially cutting into the roof sediment at other points; thus forming a hillside and a new soil, upon which new vegetation grew. As the upper coal or rider becomes thinner in proportion to the thickness of the intercolated material until it thins out altogether, additional light is thus thrown on the manner of its formation. When a seam becomes divided, the upper part never diverges for a long or indefinite distance. The parts either reunite or the upper bench continues rising until it thins to a feather edge, or is suddenly cut away. At Zaleski the intercolated material disappears in a few hundreds yards, and the two benches come together again.

There are, as all know, great areas of barren ground in the coal fields of Ohio where seams of coal are due. These barren areas have been accounted for on the theory that at the time the seams were forming there existed water spaces in the coal marsh in which the coal vegegtation never grew. No evidence in proof of this view has yet been encountered in mining operations, while the facts are as abundant as they are indisputable that many of the beds thin out and disappear on the hill sides of mines. The trough-shape marshes of the coal field, it has also been demonstrated, were formed by erosive agencies anterior to the deposition of the vegetable material from which the coal is derived. These facts explain satisfactorily the hitherto mysterious waving of the coal measures, as well as account for the wants or areas of barren ground. The wants due to the causes I have named must, however, be distinguished from the horse-backs of the miner, which are the result of neither water spaces nor subterranean hills, but of currents of water in rapid motion passing over the coal marsh in the early subsidence of the land, and cutting into the loosely matted coal vegetation, leaving a deposit of sand instead.

The swamps shifted about in the coal field with every subareal formation. Conditions favorable to the growth of a seam of coal existed, for example, in Vinton county and not in Jackson county, and so on throughout the whole coal fields. There are mines opened in coal seams in Vinton county, within eight or nine miles from where I reside, four to five feet in thickness, which have no existence, or exist as a mere trace in Jackson county. And the Wellston coal, of Jackson county, has no equivalent as a minable vein, so far as yet known, in the adjoining counties of Scioto, Vinton, or Lawrence.

Not all the seams of the series were laid down in hollow marshes formed by erosive agencies. Coal No. 2, in the northern part of the State, although it occupies a hollow swamp and an uneven floor, inherited these conditions from the steep basins in which No. 1 was laid down, in the manner which I have described in a foregoing part of this paper. In Southern Ohio also, particularly in the Hanging Rock coal fields, several beds of coal, one lying above the other stretch seemingly without break or rent in their continuity from one county to another. The development of the mines may, however, reveal facts the existence of which we can only speculate upon in the present state of mining operations.

DISCUSSION.

Mr. Cobb: I have to take exception to the last clause of that paper as to the coal of Vinton and Jackson. I think that vein has all the earmarks of being the same vein as the limestone vein in Jackson, and I see no reason why it should not be regarded as the Wellston coal. I think it is one and the same vein as the limestone vein in Jackson.

Mr. Roy: There is a slip there which was not intended. I should not have said Vinton county. I mean the counties of Lawrence, Gallia, or any other counties that have their crop on the same level. There is no question as to the existence of the Wellston coal in Vinton County.

Prof. Orton: I do not know that I have any observations to make in this connection. I have been studying the subject of coal formation for some time. I am always interested in it, and glad of any light upon the subject. But I do not know that I have any new data since I have spoken on the subject to the Society. There are a large number of problems that are unsolved, as far as any complete account is concerned. I agree in the main with the statements of the peat bog theory that has been given here this afternoon. Various points have been touched where there is plenty of room for argument, but I have a great liking for facts clearly worked out in any particular field, and presented so as to bear distinctly upon the subject; and so I do not feel that I have any special contribution to make to the discussion. It seems to me that the peat bog theory is about demonstrated. That the coal grew in beds upon the area where we find it—that it was not floated material—is the peat bog theory, and I believe all these engineers are, in the main, familiar with the doctrine. The matter of wants in the coal seams to be the best accounted for by water spaces. It looks to be altogether reasonable from all the light I have upon the subject.

Mr. Haseltine: In connection with this discussion I would like to ask this question: It has been advanced quite often that the peat was ten feet thick; that is, there was ten feet of peat for every foot of coal. I would like to know on what basis they make that calculation. Why do they calculate ten feet of peat?

Prof. Orton: By the amount of waste which the tissues show. By microscopic examination of the tissues of the coal you can see what part has been preserved. It is the harder fossils of the coal forming plants that are left. But I do not know that those figures are authoritative. They are, perhaps, the best calculation that can be made from the data we have on this subject. A number of experiments were made in this direction by a German, who carried his experiments along a number of years. He placed the plants under water, and then taking them up at various intervals of time, he found that while a great number of plants would perish entirely, there were certain parts which we find in coal—the ferns, for example—that were recorded in this durable tissue. It is along that line that the argument is made.

Mr. Morris moves that a vote of thanks be tendered Mr. Roy for his valuable paper.

Motion carried.